Run 2B Presentation to the SAG

Dave McGinnis

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SAG Questions

- What's the current parameter list?
- What are the sub-projects to support this?
- How are we doing at getting personnel assigned?
- What is the status of the subprojects that have real work going on now?
- What is the plan to get going on the others?
- How are we doing at getting a Technical Design Report released?
- What are the areas of technical uncertainty or risk
- What are the associated fallbacks / contingencies if any?
- Are we learning anything from the Run II startup that affects the plan?
- Is a linac energy upgrade part of the plan or not? Why or why not?

Current Parameter List

- The parameter List for Run 2b is **UNCHANGED**
- The luminosity goal for Run IIa is 2 fb^{-1}
  - Peak luminosity up to $2x10^{32}$ $cm^{-2}sec^{-1}$
  - Switch to 103 bunches at $1x10^{32}$ $cm^{-2}sec^{-1}$
  - Length of Run IIa is about 2 years
- The luminosity goal for Run IIa+Run IIb is 15 fb^{-1}
  - Increase antiproton intensity by 2-3
  - Peak luminosity up to $5x10^{32}$ $cm^{-2}sec^{-1}$
  - 103 bunch operation
  - Length of Run IIb is about 4 years

Run 2 Parameter List

RUN	Ib (1993-95) (6x6)	Run IIa (36x36)	Run IIa (140x105)	Run IIb (140x105)	
Protons/bunch	2.3×10^{11}	2.7×10^{11}	2.7×10^{11}	2.7×10^{11}	
Antiprotons/bunch*	5.5×10^{10}	3.0×10^{10}	4.0×10^{10}	1.0×10^{11}	
Total Antiprotons	3.3×10^{11}	1.1×10^{12}	4.2×10^{12}	1.1×10^{13}	
Pbar Production Rate	6.0×10^{10}	1.0×10^{11}	2.1×10^{11}	5.2×10^{11}	hr^{-1}
Proton emittance	23π	20π	20π	20π	mm-mrad
Antiproton emittance	13π	15π	15π	15π	mm-mrad
β^*	35	35	35	35	cm
Energy	900	1000	1000	1000	GeV
Antiproton Bunches	6	36	103	103	
Bunch length (rms)	0.60	0.37	0.37	0.37	m
Crossing Angle	0	0	136	136	μrad
Typical Luminosity	0.16×10^{31}	0.86×10^{32}	2.1×10^{32}	5.2×10^{32}	$cm^{-2}sec^{-1}$
Integrated Luminosity†	3.2	17.3	42	105	pb^{-1}/week
Bunch Spacing	~3500	396	132	132	nsec
Interactions/crossing	2.5	2.3	1.9	4.8	

†The typical luminosity at the beginning of a store has traditionally translated to integrated luminosity with a 33% duty factor. Operation with antiproton recycling may be somewhat different.

The Run 2B Plan

To obtain 15 fb^{-1} by 2007 we need to:

Increase the number of antiprotons in the collider by a factor of 2-3 over Run IIa

- without major interruption to Run IIa
- within a period of 2-3 years
- with a budget of about $35 M

The Run 2B Plan

- More Antiprotons
  - Slip Stacking -> more protons on the antiproton target (~1.8 x)
  - Better antiproton collection efficiency
    - Lithium lens Upgrade(~1.5 x)
      - Solid lens redesign
      - Liquid Lithium lens
    - AP2-Debuncher aperture increases (~1.5 x)
- Better cooling
  - Accumulator Stacktail
  - Electron cooling in the Recycler
- Better Antiproton Transfer Efficiency
- More Protons in the TEVATRON
  - TEV Tune shift compensation

Run 2B Sub-Projects (Spring 2001)

1. Slip Stacking - Steimel
2. MI Beam loading - Reid
3. AP5 line - Lebedev
4. AP2 & Debuncher Aperture Upgrades - Gollwitzer
5. Solid Lens R&D - Hurh
6. Accumulator Cooling - Derwent
7. Recycler Electron Cooling - Nagaitsev
8. Debuncher Lattice Upgrades - Werkema
9. Linac Ion Source - Dudnikov or Moehs
10. TEV Tune shift compensation - Shiltsev
11. Booster ramped correctors - Webber or designee
12. Booster cogging - Webber or designee
13. TEV. Long dampers - Tan
14. TEV Beam loading - Tan
15. Liquid Lens R&D - Leveling

Run 2B Sub-Projects (Fall 2001)

1. Slip Stacking - Steimel
2. Solid Lens R&D - Hurh
3. Liquid Lens R&D - Leveling
4. AP2 & Debuncher Aperture Upgrades - Gollwitzer
5. Accumulator Cooling - Derwent
6. Recycler Electron Cooling - Nagaitsev
7. AP5 line - Lebedev
8. TEV Tune shift compensation - Shiltsev

Eliminated Run 2b Projects

- MI Beam loading – Reid
  - Merged into Slip Stacking
- Debuncher Lattice Upgrades – Werkema
  - Merged into AP2 Aperture Upgrade
- Linac Ion Source - Dudnikov or Moehs
  - Given to the Proton Source Dept.
- Booster ramped correctors - Webber or designee
  - Given to the Proton Source Dept.
- Booster cogging - Webber or designee
  - Given to the Proton Source Dept.
- TEV. Long dampers – Tan
  - Given to the TEVATRON Dept.
- TEV Beam loading – Tan
  - Given to the TEVATRON Dept.

FY02 Budget & Manpower Request

Project	Leader	Total	M&S	Labor	Phys	Engr	Techs.	Draft	CP
Slip Stacking & MI Beam loading	Steimel	570	160	4.1	1.15	1.65	1.3	0	0
8GeV Antiproton Transfers	Lebedev	385	90	2.95	1.3	0.55	0.6	0	0.5
AP2 & Debuncher Aperture	Gollwitzer	650	90	5.6	0.9	1.5	2.2	0	1
Solid Lens R&D	Morgan	430	130	3	0.5	1	0.75	0.75	0
Accumulator Cooling	Derwent	100	0	1	0.8	0.2	0	0	0
Recycler Electron Cooling	Nagitsev	4100	2445	16.55	8.5	2.8	3.75	1	0.5
Debuncher Lattice Upgrades	Werkema	100	0	1	1	0	0	0	0
Linac Ion Source	Moehs	533	108	4.25	2	0	2.25	0	0
TEV Tune shift compensation	Shiltsev	2780	930	18.5	9	5.5	2.5	1	0.5
TEV. Beam Dynamics	Tan	70	10	0.6	0.5	0	0.1	0	0
Liquid Lens R&D	Leveling	230	200	0.3	0.2	0	0.1	0	0
Total		9948	4163	57.85	25.85	13.2	13.55	2.75	2.5

FY02 Run 2B Manpower Requested Allocation

Name	Dept.	Type	Total	Slip Stack	Pbar Trans.	AP2 Aper.	Solid Lens	Acc. Cool.	RR Cool.	Deb. Lat.	Ion Src.	BBC	TEV BD.	Liq. Lens.
CP Prof	Controls	CP	1		0.5							0.5		
Kramper	Controls	CP	0.5						0.5					
Budlong	Pbar	CP	1			1								
MS Drafter	MS	Draft	2						1			1		
O'Brien	MS	Draft	0.25				0.25							
Popper	MS	Draft	0.5				0.5							
Fuerst	Cryo	Engr	1									1		
Martinez	Cryo	Engr	0.5									0.5		
Hively	EE	Engr	0.5									0.5		
Pfeffer	EE	Engr	0.5									0.5		
Saewert	EE	Engr	1.8						0.8			1		
Hurh	MS	Engr	0.5				0.5							
Leibfritz	MS	Engr	1						1					
McGee	MS	Engr	0.5						0.5					
Ryan	MS	Engr	0.25				0.25							
Anderson	Pbar	Engr	0.75			0.75								
Peterson	Pbar	Engr	0.75			0.75								
Tang	PPD	Engr	0.25				0.25							

FY02 Run 2B Manpower Requested Allocation

Name	Dept.	Type	Total	Slip Stack	Pbar Trans.	AP2 Aper.	Solid Lens	Acc. Cool.	RR Cool.	Deb. Lat.	Ion Src.	BBC	TEV BD.	Liq. Lens.
Berenc	RF&I	Engr	0.25	0.25										
Chase	RF&I	Engr	0.1	0.1										
Crisp	RF&I	Engr	1									1		
Dey	RF&I	Engr	0.35	0.35										
Meisner	RF&I	Engr	0.1	0.1										
Pasquinelli	RF&I	Engr	0.2					0.2						
Reid	RF&I	Engr	0.1	0.1										
RFI Engr	RF&I	Engr	1.05		0.55				0.5					
Wildman	RF&I	Engr	1									1		
Steimel	TEV	Engr	0.75	0.75										
McLachlan	AP	Phys	0.25	0.25										
Bishofberger	BBC	Phys	1									1		
Kuznetsov	BBC	Phys	1									1		
Physicist	BBC	Phys	3									3		
RA	BBC	Phys	2									2		
Shiltsev	BBC	Phys	1									1		
Zhang	BBC	Phys	1									1		
Burov	EC	Phys	1						1					
Crawford	EC	Phys	1						1					
Grad student	EC	Phys	1						1					
Kroc	EC	Phys	0.5						0.5					
Nagaitsev	EC	Phys	1						1					

FY02 Run 2B Manpower Requested Allocation

Name	Dept.	Type	Total	Slip Stack	Pbar Trans.	AP2 Aper.	Solid Lens	Acc. Cool.	RR Cool.	Deb. Lat.	Ion Src.	BBC	TEV BD.	Liq. Lens.
Shemyakin	EC	Phys	1						1					
Tupikov	EC	Phys	1						1					
Warner	EC	Phys	1						1					
Koba	MI	Phys	0.75	0.75										
Kourbonis	MI	Phys	0.15	0.15										
Derwent	Pbar	Phys	0.8					0.8						
Gollwitzer	Pbar	Phys	0.7			0.7								
Harms	Pbar	Phys	0.2		0.2									
Lebedev	Pbar	Phys	1		0.6	0.2				0.2				
Leveling	Pbar	Phys	0.35				0.25							0.1
Morgan	Pbar	Phys	0.35				0.25							0.1
Sondgeroth	Pbar	Phys	0.5		0.5									
Werkema	Pbar	Phys	0.8							0.8				
Dudnikov	PS	Phys	1						0.5		0.5			
Moehs	PS	Phys	1								1			
Schmidt	PS	Phys	1						0.5		0.5			
Tan	TEV	Phys	0.5										0.5	

FY02 Run 2B Manpower Requested Allocation

Name	Dept.	Type	Total	Slip Stack	Pbar Trans.	AP2 Aper.	Solid Lens	Acc. Cool.	RR Cool.	Deb. Lat.	Ion Src.	BBC	TEV BD.	Liq. Lens.
Carlson	EC	Tech	0.5						0.5					
EE tech	EE	Tech	2.5						1			1.5		
Frett	MS	Tech	0.25						0.25					
Kellett	MS	Tech	1						1					
Kelly	MS	Tech	0.85				0.75							0.1
MS Tech	MS	Tech	0.95			0.2					0.25	0.5		
Nelson	MS	Tech	1						1					
Dilday	Pbar	Tech	1			1								
Obie	Pbar	Tech	0.2		0.2									
Pbar Tech	Pbar	Tech	1			1								
Hren	PS	Tech	1								1			
Wendt	PS	Tech	1								1			
Holm	RF&I	Tech	0.15	0.15										
Olson	RF&I	Tech	0.5									0.5		
RF&I Tech	RF&I	Tech	0.4		0.4									
VanBogaert	RF&I	Tech	0.15	0.15										
Zifko	RF&I	Tech	0.15	0.15										
Koch	TEV	Tech	0.6	0.5									0.1	
McCormack	TEV	Tech	0.35	0.35										
Total			57.9	4.1	2.95	5.6	3	1	16.6	1	4.25	18.5	0.6	0.3

Run 2B Technical Progress

- Slip Stacking – Steimel
  - Fundamental beam loading compensation tested at 26 dB of gain
  - Tracking studies without beam loading completed
    - Longitudinal blowup ~ 50%
  - Initial tracking studies with beam loading completed
    - 40 dB of loop gain
  - Detailed tracking studies of slip stacking with beam loading underway.
  - Low level RF hardware and software for slip stacking mechanics completed and tested.
  - **Two low intensity (2 booster turns) have been slip stacked in the Main Injector with close to 100% efficiency at 8 GeV !!!!!**

Run 2B Technical Progress

- Solid Lens R&D – Hurh
  - Modeling of current lens with MARS and ANSYS fairly mature. (P. Bussey and A. Leveling)
  - Diffusion Bonded Prototypes
    - 3 Diffusion Bonded Prototype Lens bodies have been fabricated.
    - Each prototype has been sectioned and every joint has been analyzed
    - Each successive prototype has incorporated design changes from previous prototype
    - Fatigue testing of diffusion bonded joints compared to ebeam welded joints is ready to go but is on hold due to budget problems
- Liquid Lens R&D – Leveling
  - Extension (Amendment 7) of Phase 3 of the Liquid Lithium Accord has been granted ($150k)
  - Expect the liquid lithium pumping contour and power supply by late 2001 – early 2002 to arrive at FNAL

Run 2B Technical Progress

- AP2 & Debuncher Aperture Upgrades – Gollwitzer
  - NO beam studies on the Debuncher or AP2 has been done since February 2001.
    - All Pbar studies aimed at 8 GeV pbar transfer efficiency
  - First phase of Debuncher motorized quad stands to might be (resource limited) installed this October shutdown.
  - First phase of AP2 trims might be (resource limited) installed this October shutdown.
  - Electrical design of the Debuncher BPM analog front-end started.
  - Collaboration with Ohio State on Debuncher BPM system DAQ system on hold.

Run 2B Technical Progress

- Accumulator Cooling – Derwent
  - No real work done yet.
  - Bottle-neck of Run 2a stacking rate traced to instabilities in StackTail sytem
    - New compensation electronics in StackTail to be installed in October shutdown
- Recycler Electron Cooling – Nagaitsev
  - High voltage commissioning of Pelletron finished.
  - High voltage- low current recirculation thru the U-bend established
  - Low voltage - high current recirculation commissioning underway.
  - New Pelletron high voltage tubes to be installed late 2001 – early 2002
  - MI-30 Civil engineering design to start in early FY02

Run 2B Technical Progress

- AP5 line - Lebedev
  - All Pbar studies since Feb 2001 aimed at 8 GeV pbar transfer efficiency
  - Remnant field properties of the p1-AP3 line have been measured and understood.
  - 3 versions of a new 8 GeV lattice have been attempted
    - Each lattice requires a complementary P1-AP1 120 GeV lattice
  - Preliminary measurements indicate that a separate 8 GeV line will not be needed.
    - A very structured hysteresis protocol needs to be developed
    - 8 GeV pbar injection damper has been identified as crucial but still awaits engineering.

Run 2B Technical Progress

- TEV Tune shift compensation – Shiltsev
  - Linear tune shift of bunches in TEVATRON at 150 GeV observed with prototype lens at A0
    - Proton lifetime with lens on is 20 hrs
  - Due to TEV failures and poor Run 2A performance, very few shifts have been allocated to TEV tuneshift compensation project.
  - Second lens on hold until lifetime problems with first lens are understood.

Technical Design Report Status

- Initial document released on May 20 for AAC meeting.
- Second draft TDR assignments handed out on 9/10/01
- Second draft due on Nov. 1, 2001
- Final draft due on Dec. 1, 2001
- AAC meeting Dec. 11-12, 2001

Technical Design Report Status

- Outline of Sections
  - Goal / Potential
  - Machine physics
  - Technical
  - Project Plan
    - State succinctly what is in the plan. Discuss how long to complete the whole project.
    - Current status what has been done as of end of FY2001
    - FY2002 Plans
    - This should match to the current manpower and dollar plans.
    - It would be interesting to be explicit about what is the limiting factor / ... physicists, engineers, beam time, dollars or whatever.
    - FY2003 Plans
  - Summary

Areas of Technical Uncertainty

- Slip Stacking
  - Is 40 dB of beam loading compensation possible?
- Solid Lens R&D
  - Will diffusion bonding result in lower fatigue stresses?
- Liquid Lens R&D
  - What isn't uncertain?
- AP2 & Debuncher Aperture Upgrades
  - Will large acceptance but fixed lens radius result in AP2 lattice functions that are unacceptable?
- Accumulator Cooling
  - Will high stacktail gain result in core instabilities that can be compensated?

Areas of Technical Uncertainty

- Recycler Electron Cooling
  - Can we achieve high recirculation efficiency?
  - Can the 5 MeV electron beam survive a Main Injector 120 GeV ramp?
  - Will the Recycler ever work?
- AP5 line
  - Can the tune-up procedures, software, and control system permit 1-2 minute shot setups to the Recycler?
- TEV Tune shift compensation
  - Can we get the proton lifetime with the lens on to > 100 hrs?
  - Will the lens drive beam resonances more than it can compensate tuneshifts?
  - Is non-linear compensation possible?
    - Linear compensation will not help 132 nS that much.
  - How difficult are the controls for bunch by bunch compensation?

Lessons Learned from Run 2A Startup

- Will the Recycler ever work?
- Never skimp on beam line design.
- Never skimp on diagnostics.
- For stochastic cooling, a faster cooling rate implies LOWER peak antiproton stacks.
- Increasing the number of bunches in the TEVATRON while keeping the single bunch intensity fixed does result in more charge in the TEVATRON

Linac Energy Upgrade

- The Linac 400 MeV Upgrade
  - Gave an increase of 1.75 (beta * gamma^2) on paper
  - Cost about 30~50 M$
  - Took 4-5 years to build
  - Required exceptional RF expertise
  - Shutdown the Accelerator Complex for an extended period of time (not including commissioning)
- The 600 MeV Upgrade
  - Gives a 1.45 increase on protons at 600 MeV in the Booster (on paper)
  - Should cost the same as the 400 MeV upgrade
  - Should take at least the same amount of time to build as the 400 MEV Upgrade.
  - Should require the same amount of RF expertise.
  - Would shutdown the Accelerator for at least 6 months to install.